https://doi.org/10.21070/nabatia.v13i2.1672

The Evaluation of the Effectiveness of Organic and Mineral Fertilization (NPK) in Improving the Vegetative and Productive Traits of Strawberry (Fragaria × ananassa)

Noor Alhuda Hameed Hassan [1],Rawaa Abd Basheer[2], Nasr shukri drar al-alosi [3]

[1] Department of Horticulture and Landscape Engineering, College of Agriculture – University of Samarra

[2, 3] Department of Horticulture and Landscape Engineering, College of Agriculture – University of Tikrit

*Corresponding author. Email: Noor.h.hasan@uosamarra.edu.iq

Abstract. Ruminant The study was conducted in an unheated plastic greenhouse at the University of Tikrit (2022–2023) to evaluate the effect of organic and mineral fertilizers on strawberry (Fragaria × ananassa) productivity. Organic treatments included mushroom waste (M1), poultry manure (M2), and a control, combined with three NPK mineral fertilizer levels (0, 0.75, and 1 g L^{-1}). A randomized complete block design (RCBD) with three replications was used, and data were analyzed using L.S.D at the 0.05 probability level. Results showed that M1 produced the highest number of leaves (31.19 leaves $plant^{-1}$), compared to M2 (28.59) and the control (27.69). For mineral fertilization, 1 g L^{-1} resulted in 30.25 leaves $plant^{-1}$, higher than 0.75 g L^{-1} (26.22), while 0 g L^{-1} gave 30.94. No significant interaction was found between organic and mineral fertilization for this trait. Average leaf area showed no significant differences among organic treatments (32.78–35.11 cm^2) or mineral levels (33.89–34.67 cm^2). Leaf nitrogen (0.996–1.334%) and phosphorus (0.11699–0.12213%) contents also showed no significant variation. In contrast, leaf potassium content was significantly affected. M2 recorded the highest value (1.643%), followed by M1 (1.375%), while the control gave the lowest (1.028%). For mineral fertilization, 0 g L^{-1} (1.433%) outperformed 0.75 (1.363%) and 1 g L^{-1} (1.303%). A significant interaction was observed for potassium content, with L.S.D values confirming the combined influence of organic and mineral fertilization.

Keywords: Strawberry, Organic fertilization, Mineral fertilization, Vegetative traits, Productive traits

INTRODUCTION

Strawberry (Fragaria × ananassa Duch.) is one of the most important fruit and vegetable crops due to its high economic and nutritional value. It is consumed fresh and also used in a variety of food industries. Strawberries are particularly rich in vitamins and antioxidants, especially vitamin C and flavonoids [1], [2]. With the increasing global demand for strawberries, it has become essential to develop sustainable agricultural practices that ensure high yield and quality while maintaining soil health and protecting the environment [3]. One of the major challenges in strawberry production is the high cost of chemical fertilizers, in addition to their negative environmental impacts such as nitrate contamination of groundwater and reduced soil biological activity when excessively applied [4]. Therefore, recent studies have focused on the use of organic fertilizers and agricultural or animal residues as alternatives or supplements to mineral fertilizers, under the concept of Integrated Fertilization Management (IFM) [5].

Spent mushroom substrate (SMS) is considered a valuable agricultural by-product rich in organic matter and essential nutrients, including nitrogen, phosphorus, and potassium. In addition, it improves soil structure and enhances water retention capacity [6], [7]. Reusing SMS also contributes to reducing environmental pollution caused by its accumulation at production sites.

Similarly, poultry manure is recognized as a nutrient-rich organic fertilizer containing high levels of nitrogen, phosphorus, and micronutrients. It has been proven to improve vegetative growth and yield in many crops, including strawberry [8], [9]. Moreover, poultry manure enhances microbial activity and increases soil fertility.

Although organic fertilizers provide substantial benefits, relying solely on them may not fully meet the nutritional requirements of a high-yielding crop such as strawberry. Mineral fertilizers (NPK), on the other hand, supply essential macronutrients rapidly and efficiently, but their excessive use leads to environmental and agronomic issues, as mentioned earlier. Therefore, combining organic sources (such as mushroom and poultry wastes) with mineral fertilizers (NPK) represents a strategic approach to achieving high productivity while maintaining ecological balance [10].

Based on this context, the present study was designed to evaluate the effects of mushroom and poultry residues (as the first factor) in combination with different levels of NPK fertilizer (as the second factor) on the growth and productivity of strawberry [11], [12]. The aim was to determine integrated fertilization treatments that achieve maximum yield and fruit quality while ensuring long-term soil sustainability.

MATERIALS AND METHODS

A. Experimental Site and Soil Sampling

The experiment was conducted during the 2022–2023 growing season in an unheated plastic greenhouse belonging to the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Tikrit. The purpose of the study was to evaluate different organic fertilization programs on the productivity of strawberry (Fragaria × ananassa).

For the purpose of soil chemical and physical analyses, soil samples were collected from the experimental field at depths of 0–30 cm from several locations within the greenhouse. Laboratory analyses of the soil were carried out at the Soil and Water Laboratories, College of Agriculture, University of Tikrit. The physical and chemical characteristics of the soil used in the experiment are presented in Table (1).

Table 1. Physical and chemical properties of the experimental soil\

Sand (%)	37.0
Silt (%)	26.0
Clay (%)	37.0
Soil texture	Clay loam sandy

Soil pH	7.15
Elektrical conductivity (EC) (dS m^{-1}, 25°C)	3.35
Organic Matter (g kg^{-1})	0.967
Nitrate (NO_3^-, mg kg^{-1})	10.13
Ammonium (NH_4^+, mg kg^{-1})	9.12
Phosphorus (mg kg^{-1})	11.2
Potassium (mg kg^{-1})	2.0

B. Soil Preparation

On July 1, 2022, the soil of the plastic greenhouse was prepared through primary agricultural operations. Weeds and plant residues were removed, followed by shallow tillage using a disk harrow. The soil was then leveled and solarized by covering it with transparent polyethylene sheets after installing drip irrigation lines beneath the cover. The soil was irrigated twice during the solarization period to destroy weed seeds [13]. After 60 days, the plastic sheets were removed, and the land was divided into five ridges, three of which were selected for the experiment. Each ridge was 60 cm wide at the base, 40 cm at the top, and 30 cm high. The planting distance was 25 cm between plants, with a spacing of 1 m between experimental units and ridges [14].

The greenhouse was covered with yellow polyethylene film (200 microns thick), while mesh fabric was used on the doors to prevent insect entry. Strawberry seedlings were transplanted on both sides of the ridges in a triangular arrangement. Before planting, the soil was irrigated, and black polyethylene mulch was applied to the ridges to reduce weed growth and conserve soil moisture [15], [16]. The mulch edges were tightly fixed with soil.

C. Plant Material

Strawberry seedlings of the cultivar Albion, propagated through tissue culture, were obtained from Jana Al-Nakheel Company, Baghdad. The seedlings were originally grown in special plastic trays, then transplanted into the experimental field with immediate irrigation to ensure successful establishment.

D. Planting

Planting was carried out on November 15, 2022, during the early morning hours. After transplantation, seedlings were given a heavy irrigation, followed by regular agricultural practices and maintenance. Flowers formed during the first two weeks after planting were removed to encourage vegetative and root growth [17]. The spring harvest was later adopted for sampling and trait evaluation.

E. Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications to ensure accuracy and minimize the effect of uncontrolled environmental factors. Two main factors were studied:

F. Fertilization programs (m):

- M1: Mushroom waste extract

- M2: Poultry manure extract
- Control (no organic fertilization)

  Organic treatments were applied in the form of liquid extracts with ratios of 0:0, 3 poultry waste:7 water, and 3 mushroom waste:7 water. Applications were carried out six times during the growing season, starting 45 days after planting.

Mineral fertilizer (NPK)

Three levels of NPK fertilizer were applied: 0, 0.75, and 1 g L^{-1}, in order to compare the effects of organic, chemical, and combined fertilization programs. Treatments were randomly distributed within the three blocks, and all standard agricultural practices were followed.

Measured Traits

Vegetative traits

- **Average number of leaves (leaves $plant^{-1}$):**
  The number of leaves was counted on five randomly selected plants from each experimental unit at the end of the growing season. The values were averaged to obtain the mean number of leaves per plant.

- **Leaf area (cm^2 $plant^{-1}$):**
  The average leaf area was calculated according to the method described by Morsi et al. (1968).

Chemical traits

- **Leaf mineral content**

  Recently matured leaves with their petioles were collected (Morgan, 2006) after the fruits reached maturity and nutrient concentrations stabilized. Leaves were washed with distilled water to remove dust, oven-dried at 70°C until constant weight, and ground to pass through a 0.2 mm sieve [18], [19]. Samples were digested using a mixture of sulfuric and perchloric acids as described by Al-Sahaf. Nutrient contents were then determined as follows:
- **Nitrogen (N, %):** Determined by the Micro-Kjeldahl method (Jackson, 1958).
- **Phosphorus (P, ppm):** Measured using ammonium molybdate and ascorbic acid, and absorbance was read with a UV–VIS Spectrophotometer (Model 80D) at 662 nm (Olsen & Sommers, 1982).
- **Potassium (K, %):** Estimated using a Flame Photometer (Al-Sahaf, 1989b).

RESULTS AND DISCUSSION

A. Effect of Organic Fertilizers, Mineral Fertilizers, and Their Interaction on the Average Number of Leaves (leaves $plant^{-1}$) of Strawberry

The organic fertilizer treatment M1 (mushroom waste) significantly increased the average number of leaves, recording 31.19 leaves plant⁻¹, and was superior to both M2 (poultry manure) and the control treatment, which recorded 28.59 and 27.69 leaves plant⁻¹, respectively.

Regarding mineral fertilizer (NPK), the treatment of 1 g L⁻¹ resulted in the highest number of leaves (30.25 leaves plant⁻¹) compared to the treatments of 0 g L⁻¹ and 0.75 g L⁻¹, which recorded 30.94 and 26.22 leaves plant⁻¹, respectively [20].

As for the interaction between organic and mineral fertilizers, no significant differences were observed at the 0.05 probability level, indicating that the effect of each factor was independent and not influenced by their combination.

Table 2. Effect of organic fertilizer, mineral fertilizer, and their interaction on the average number of leaves (leaves plant⁻¹) of strawberry

Average of organic fertilizer	Average number of leaves (leaves plant⁻¹)			Npk
	1L.g1-	0.75 L.g1-	0 L.g1-	Organic fertilization
27.62	29.20	22.33	31.34	Control
31.19	31.23	30.33	32.01	M1
28.59	30.31	26.00	29.47	M2
	30.25	26.22	30.94	average npk
interaction between organic and mineral fertilization	mineral fertilization	Organic fertilization		L.S.D
N.S	1.774	2.787		

B. Effect of Organic Fertilization, Mineral Fertilization, and Their Interaction on Leaf Area (cm²) of Strawberry

The results presented in Table (3) show that organic fertilization treatments did not exhibit significant differences in the average leaf area among the different programs. The averages were 32.78, 34.78, and 35.11 cm² leaf⁻¹ for the Control, M1 (mushroom waste), and M2 (poultry manure) treatments, respectively.

Regarding mineral fertilization (NPK), the concentrations of 0, 0.75, and 1 g L⁻¹ recorded average values of 34.11, 34.67, and 33.89 cm² leaf⁻¹, respectively, with no significant differences among them.

Furthermore, no significant interaction was observed between organic fertilization and mineral NPK levels in this trait at the 0.05 probability level, indicating that both factors acted independently.

Table 3. Effect of organic fertilization, mineral fertilization, and their interaction on leaf area (cm²) of strawberry

Average of organic fertilizer	Leaf Area (cm²)			Npk
	1L.g1-	0.75 L.g1-	0 L.g1-	Organic fertilization
32.78	32.33	33.67	32.33	Control
34.78	34.67	35.00	34.67	M1
35.11	34.67	35.33	35.33	M2
	33.89	34.67	34.11	average npk
interaction between organic and mineral fertilization	mineral fertilization	Organic fertilization		L.S.D
N.S	N.S	N.S		

C. Effect of Organic Fertilization, Mineral Fertilization, and Their Interaction on Leaf Nitrogen Content (%) of Strawberry

The results presented in Table (4) indicate that neither the control nor the organic fertilization treatments (M1 and M2) showed significant differences in leaf nitrogen content. The recorded values were 0.996, 1.334, and 1.252% for Control, M1 (mushroom waste), and M2 (poultry manure), respectively.

Similarly, mineral fertilization (NPK) at the concentrations of 0, 0.75, and 1 g L^{-1} resulted in average values of 2.23, 1.11, and 2.43%, respectively, with no significant differences observed among them.

Furthermore, no significant interaction was detected between organic and mineral fertilization at the 0.05 probability level, suggesting that the effects of both factors were independent and did not produce any combined impact.

Table 4. Effect of organic fertilization, mineral fertilization, and their interaction on leaf nitrogen content (%) of strawberry

Average of organic fertilizer	N %			Npk
	1L.g1-	0.75 L.g1-	0 L.g1-	Organic fertilization
0.996	1.137	0.758	2.074	Control
1.334	0.038	1.415	2.232	M1
1.252	1.255	1.156	2.373	M2
	2.430	1.11	2.23	average npk
interaction between organic	mineral fertilization	Organic fertilization		L.S.D

and mineral fertilization			
N.S	**N.S**	**N.S**	

D. Effect of Organic Fertilization, Mineral Fertilization, and Their Interaction on Leaf Phosphorus Content (%) of Strawberry

The results presented in Table (5) show that organic fertilization treatments (Control, M1, and M2) did not exhibit significant differences in leaf phosphorus content. The recorded values were 0.11699, 0.11840, and 0.12213% for Control, M1 (mushroom waste), and M2 (poultry manure), respectively.

Similarly, mineral fertilization (NPK) at concentrations of 0, 0.75, and 1 g L^{-1} resulted in mean values of 0.11895, 0.11783, and 0.11953%, respectively, with no significant differences detected among them.

Moreover, no significant interaction was observed between organic and mineral fertilization at the 0.05 probability level, indicating that the effects of both factors were independent and did not produce any combined effect.

Table 5. Effect of organic fertilization, mineral fertilization, and their interaction on leaf phosphorus content (%) of strawberry

Average of organic fertilizer		P %		Npk
	1L.g^{1-}	**0.75** L.g^{1-}	0 L.g^{1-}	Organic fertilization
0.11699	0.11905	0.11731	0.11571	Control
0.11840	0.11967	0.11882	0.11946	M1
0.12213	0.11988	0.11737	0.12169	M2
	0.11953	0.11783	0.11895	average npk
interaction between organic and mineral fertilization	mineral fertilization	Organic fertilization		L.S.D
N.S	N.S	N.S		

E. Effect of Organic Fertilization, Mineral Fertilization, and Their Interaction on Leaf Potassium Content (%) of Strawberry

The results presented in Table (6) show that organic fertilization had a significant effect on leaf potassium content. The treatment with **M2 (poultry manure)** recorded the highest mean value (**1.643%**), followed by **M1 (mushroom waste)** with an average of **1.375%**, while the **Control** treatment gave the lowest value (**1.028%**).

Regarding mineral fertilization (NPK), the **0 g L⁻¹** treatment significantly outperformed the other concentrations with a mean value of **1.433%**, compared to **0.75 g L⁻¹** and **1 g L⁻¹**, which recorded **1.363%** and **1.303%**, respectively.

As for the interaction between organic and mineral fertilization, a significant effect was observed at the 0.05 probability level. The least significant difference (L.S.D) values were **0.1545** for organic fertilization, **0.0774** for mineral fertilization, and **0.1971** for the interaction, confirming the presence of a meaningful combined influence (Table 6).

Table 6. Effect of organic fertilization, mineral fertilization, and their interaction on leaf potassium content (%) of strawberry

Average of organic fertilizer	**K %**			**Npk**
	$1L.g^{1-}$	**0.75 $L.g^{1-}$**	**0 $L.g^{1-}$**	**Organic fertilization**
1.028	**1.050**	**1.075**	**1.050**	**Control**
1.375	**1.530**	**1.310**	**1.285**	**M1**
1.643	**1.720**	**1.705**	**1.505**	**M2**
	1.303	**1.363**	**1.433**	**average npk**
interaction between organic and mineral fertilization	**mineral fertilization**	**Organic fertilization**		**L.S.D**
0.1971	0.0774	0.1545		

The organic program M1 (mushroom waste) significantly outperformed other treatments in terms of average number of leaves, recording 31.19 leaves plant⁻¹, compared to M2 (poultry manure, 28.59 leaves plant⁻¹) and the Control (27.69 leaves plant⁻¹). This superiority may be attributed to the fact that mushroom waste is rich in easily decomposable organic compounds, which improve soil physical properties and stimulate microbial activity, thereby enhancing the availability of essential nutrients such as nitrogen, phosphorus, and potassium required for vegetative growth. In contrast, poultry manure may decompose more slowly or have a nutrient profile that is less balanced, which makes its effect relatively weaker compared to mushroom residues.

For mineral fertilization, the 1 g L⁻¹ NPK treatment recorded 30.25 leaves plant⁻¹, surpassing the 0.75 g L⁻¹ treatment (26.22 leaves plant⁻¹), while the 0 g L⁻¹ treatment gave a comparable value (30.94 leaves plant⁻¹). This indicates that the medium level of NPK (0.75 g L⁻¹) may not fully meet the crop's nutritional requirements, or may cause nutrient imbalances, while either the absence of NPK or its higher concentration enabled the plants to achieve better vegetative performance.

The absence of significant differences in the interaction between organic and mineral fertilization at the 0.05 probability level suggests that both factors acted independently without producing a synergistic or antagonistic effect. Such a pattern is often observed in field experiments when soil nutrient levels are already sufficient or when environmental conditions are favorable for plant growth.

Some of the results also revealed no significant differences between organic and mineral fertilization treatments. For example, the Control, M1, and M2 treatments recorded similar averages (32.78, 34.78, and 35.11 leaves plant^{-1}, respectively). Likewise, NPK concentrations (0, 0.75, and 1 g L^{-1}) showed means of 34.11, 34.67, and 33.89, respectively, with no significant differences. This indicates that environmental conditions or the inherent soil nutrient content were adequate to support comparable growth across treatments, thus reducing the likelihood of significant statistical variation.

In terms of potassium content, the M2 (poultry manure) treatment recorded the highest value (1.643%), followed by M1 (mushroom waste, 1.375%), while the Control recorded the lowest (1.028%). This superiority is explained by the fact that poultry manure is a rich source of readily available potassium and enhances microbial activity in the soil, which increases the availability of K and other nutrients.

For NPK, the 0 g L^{-1} treatment significantly outperformed the other concentrations, with a mean of 1.433%, compared to 0.75 g L^{-1} (1.363%) and 1 g L^{-1} (1.303%). This suggests that higher levels of mineral fertilization may sometimes result in competition between nitrogen and potassium ions at the root absorption sites, thereby reducing the efficiency of potassium uptake at higher NPK levels.

The statistical values for least significant difference (L.S.D) — 0.1545 for organic fertilization, 0.0774 for mineral fertilization, and 0.1971 for the interaction — confirm that the differences in leaf potassium content were significant. This indicates that both organic and mineral fertilization independently affected potassium accumulation, while their interaction also had a significant effect, suggesting that combining organic amendments with appropriate doses of NPK may produce a more pronounced improvement in leaf K content

REFERENCES

[1.] E. B. S. Ewulo, S. O. Ojeniyi, and D. A. Akanni, "Effect of Poultry Manure on Selected Soil Physical and Chemical Properties, Growth, Yield and Nutrient Status of Tomato," African Journal of Agricultural Research, vol. 3, no. 9, pp. 612–616, 2008.

[2.] F. Giampieri, S. Tulipani, J. M. Alvarez-Suarez, J. L. Quiles, B. Mezzetti, and M. Battino, "The Strawberry: Composition, Nutritional Quality, and Impact on Human Health," Nutrition, vol. 28, no. 1, pp. 9–19, 2012, doi: 10.1016/j.nut.2011.08.009.

[3.] J. F. Hancock, Strawberries. Wallingford, UK: CABI Publishing, 1999.

[4.] P. Marschner, Marschner's Mineral Nutrition of Higher Plants, 3rd ed. London, UK: Academic Press, 2012.

[5.] K. Möller, "Influence of Different Manuring Systems with and without Biogas Digestion Residues on Soil Organic Matter and Nitrogen Inputs, Balances and Soil Fertility," Renewable Agriculture and Food Systems, vol. 24, no. 3, pp. 204–218, 2009.

[6.] S. Savci, "An Agricultural Pollutant: Chemical Fertilizer," International Journal of Environmental Science and Development, vol. 3, no. 1, pp. 77–80, 2012.

[7.] R. H. Zhang, X. Li, and M. Fenton, "Potential Use of Spent Mushroom Substrate as a Soil Amendment and Nutrient Source," Science of the Total Environment, vol. 419, pp. 283–289,

2012.
[8.] O. P. Ahlawat and M. P. Sagar, "Management of Mushroom Crop Residues for Sustainable Soil Health," Indian Journal of Mushroom, vol. 25, no. 2, pp. 37–44, 2007.
[9.] M. M. Hussein and S. Radwan, "Effect of Chicken Manure on Soil Properties and Growth of Some Crops," Egyptian Journal of Soil Science, vol. 41, no. 1–2, pp. 113–126, 2001.
[10.] E. Liu, C. Yan, X. Mei, Y. Zhang, T. Fan, and N. C. Turner, "Long-Term Effect of Chemical Fertilizer, Straw, and Manure on Soil Chemical and Biological Properties in Northwest China," Geoderma, vol. 158, no. 3–4, pp. 173–180, 2014.
[11.] P. Marschner, Marschner's Mineral Nutrition of Higher Plants, 3rd ed. London, UK: Academic Press, 2012.
[12.] K. Mengel and E. A. Kirkby, Principles of Plant Nutrition, 5th ed. Dordrecht, Netherlands: Kluwer Academic Publishers, 2001.
[13.] A.Sharma and R. Singh, "Impact of Integrated Nutrient Management on Growth and Yield of Strawberry," Indian Journal of Horticulture, vol. 68, no. 2, pp. 210–214, 2011.
[14.] X. Zhao, Z. Chen, and Z. Shen, "Effects of Spent Mushroom Substrate on Growth and Yield of Crops: A Review," Plant and Soil, vol. 426, no. 1–2, pp. 345–362, 2016.
[15.] M. L. Morgan, Hydroponic Strawberry Production: A Technical Guide to the Hydroponic Production of Strawberries. Tokomaru, New Zealand: Suntec (NZ) Ltd, 2006, p. 118.
[16.] M. L. Jackson, Soil Chemical Analysis. Englewood Cliffs, NJ, USA: Prentice Hall, Inc., 1958, pp. 225–276.
[17.] S. R. Olsen and L. E. Sommers, "Phosphorus," in Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties, 2nd ed., A. L. Page, Ed. Madison, WI, USA: American Society of Agronomy, Soil Science Society of America, 1982, pp. 403–430.
[18.] F. H. Al-Sahaf, Applied Plant Nutrition. Baghdad, Iraq: Ministry of Higher Education and Scientific Research, University of Baghdad – Bayt Al-Hikma, 1989.
[19.] W. Abu-Gharbieh, "Practical Applications of Soil Solarization for Protected Agriculture," in Expert Consultation Meeting on Integrated Production and Protection Management for Protected Agriculture in the Arabian Peninsula, Dubai, United Arab Emirates, Arabian Peninsula Regional Program, ICARDA, 2000.
[20.] M. A. Morsi, H. A. Taufiq, and A. A. Abdel-Gawad, Fundamentals of Agricultural Research. Cairo, Egypt: Anglo-Egyptian Library, 1968, p. 631.

Conflict of Interest Statement:*The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*